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Higher regular fat dairy consumption is associated with lower incidence of metabolic syndrome but not type 2 diabetes

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Abstract

Background and aims Limited evidence suggests habitual dairy consumption to be protective against metabolic syndrome (MetSyn) and type 2 diabetes among older adults. We assessed the association of baseline consumption of dairy products with the incidence of MetSyn and type 2 diabetes among a cohort of Australian adults aged 49 years and over. Methods and results A validated 145-item semi-quantitative food frequency questionnaire was used to assess food and nutrient intake at baseline. Ten-year incidence of MetSyn and type 2 diabetes were obtained from 1807 and 1824 subjects respectively. Odds ratios (OR) were calculated by discrete time logistic regression modelling. Compared with subjects in the lowest intake quartile of regular fat dairy products, those in the highest quartile had a 59% lower risk of MetSyn (multivariate adjusted OR: 0.41; 95% CI: 0.23-0.71; ptrend = 0.004), after adjustment for risk factors. Among obese subjects, an association between a high intake of regular fat dairy foods and reduced risk of type 2 diabetes was also found (age and sex adjusted OR 0.37; 95% CI: 0.16-0.88; ptrend = 0.030), but the association did not persist after adjustment for additional confounders. There was no association between total dairy consumption and risk of MetSyn or type 2 diabetes. Conclusions We found an inverse association between regular fat dairy consumption and risk of MetSyn among Australian older adults. Further studies are warranted to examine the association between weight status, dairy consumption and risk of type 2 diabetes.

Keywords

metabolic, incidence, lower, associated, consumption, dairy, fat, regular, higher, but, syndrome, not, diabetes, type, 2

Disciplines

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Higher regular fat dairy consumption is associated with lower incidence of metabolic syndrome but not type 2 diabetes

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ABSTRACT

BACKGROUND AND AIMS: Limited evidence suggests habitual dairy consumption to be protective against metabolic syndrome (MetSyn) and type 2 diabetes among older adults. We assessed the association of baseline consumption of dairy products with the incidence of MetSyn and type 2 diabetes among a cohort of Australian adults aged 49 years and over.

METHODS AND RESULTS: A validated 145-item semi-quantitative food frequency questionnaire was used to assess food and nutrient intake at baseline. Ten-year incidence of MetSyn and type 2 diabetes were obtained from 1,807 and 1,824 subjects respectively. Odds ratios (OR) were calculated by discrete time logistic regression modelling. Compared with subjects in the lowest intake quartile of regular fat dairy products, those in the highest quartile had a 59% lower risk of MetSyn (multivariate adjusted OR: 0.41; 95% CI: 0.23-0.71; p_{trend} = 0.004), after adjustment for risk factors. Among obese subjects, an association between a high intake of regular fat dairy foods and reduced risk of type 2 diabetes was also found (age and sex adjusted OR 0.37; 95%CI: 0.16-0.88; p_{trend} = 0.030), but the association did not persist after adjustment for additional confounders. There was no association between total dairy consumption and risk of MetSyn or type 2 diabetes.

CONCLUSIONS: We found an inverse association between regular fat dairy consumption and risk of MetSyn among Australian older adults. Further studies are warranted to examine the association between weight status, dairy consumption and risk of type 2 diabetes.

(240 words)

INTRODUCTION

Metabolic syndrome (MetSyn) and type 2 diabetes share common features such as abnormal glucose homeostasis, elevated blood lipids, and often central obesity. Indeed type 2 diabetes is considered a component of MetSyn by most international definitions [1-4]. MetSyn was deemed one of the fasting growing diseases in the world [5, 6]. Instead of a true syndrome, it is best described as a set of risk factors related to increased risks of cardiovascular diseases [7]. In 1999 – 2000, it was estimated that around 29% of Australian adults aged 25 years or older had MetSyn [8].

Diet and lifestyle changes are important in the prevention of MetSyn [9, 10] and type 2 diabetes [11, 12]. Among many foods that may offer protection against MetSyn or type 2 diabetes, dairy products are one of the most frequently investigated food groups. However, due to the paucity of prospective studies, evidence on the effects of dairy consumption on risk of MetSyn is inconclusive [13]. While the Hoorn study [14] in the Netherlands found no association between dairy consumption (regardless of type) and risk of MetSyn, other studies [7, 15, 16] suggested dairy intake was protective for MetSyn.

Similarly, some studies [5, 17] show no relationship between dairy consumption and risk of type 2 diabetes but dairy consumption is generally considered to be protective of type 2 diabetes [12, 18], mainly driven by the findings of large scale studies. In a study of 37.183 older women with an average follow up period of 10 years [19], a significant negative dose-dependent relationship between total dairy intake and type 2 diabetes incidence was found, although the protective effect was only seen amongst individuals without a family history of type 2 diabetes. On the other hand, Choi *et al* [20] reported a protective effect of total dairy or low fat dairy amongst 41 254 American males aged 40 – 70 y on type 2 diabetes, regardless of family history of diabetes.

Overall, the limited evidence in older adults [7, 19, 20] suggests dairy consumption may be protective of MetSyn and/or type 2 diabetes in this age group. To the best of our knowledge no study had examined the effects of habitual dairy consumption and risk of these two conditions in older Australians. Here we report on the association between dairy consumption with the ten-year incidence of MetSyn and type 2 diabetes in a relatively large cohort of Australians aged 49 years and above.

METHODS

Study population

The details of the Blue Mountains Eye Study (BMES) have been previously reported [21]. In brief, the BMES is a population-based cohort study of common eye diseases and other health conditions in residents aged 49 years and over in the Blue Mountains area, west of Sydney, Australia. Baseline information was obtained during 1992 – 1994. A total of 3 267 participants (89.4% of enrolled participants) attempted and returned the food frequency questionnaire (FFQ), of which 2 900 were usable (79.3% of participants examined). The details of the FFQ data cleaning process have been reported elsewhere [21]. At ten-years, in 2002-04, 1 824 people who provided complete FFQ data at baseline attended follow-up examinations including anthropometric and biochemical assessments, and were included in the present analysis.

Dietary assessment

Dietary data were collected using a 145-item self-administered semi-quantitative FFQ, modified for the Australian diet and vernacular from an earlier FFQ by Willett *et al* [22]. Participants used a 9-category frequency scale to indicate the usual frequency of consuming individual food items during the past year. An allowance for seasonal variation of fruit and vegetables was made by weighting seasonal fruits and vegetables. Dietary intakes were reassessed by the same FFQ every 5 years. The validity of the FFQ has been reported elsewhere [23, 24]. The Spearman correlation coefficient for total calcium was 0.61, with 71% of calcium results ranked within one quintile when compared to the weighed food records (WFR) and only 1% of calcium results were grossly misclassified (i.e. ranked highest by FFQ method and lowest by WFR method, or vice-versa). Published glycemic index (GI) values [25] were assigned to the food items in the FFQ, and the dietary GI and glycemic load (GL) were calculated for each subject as $\frac{\sum_{i=1}^{j} \mathrm{GI}_i \times \mathrm{CHO}_i}{\sum_{i=1}^{j} \mathrm{CHO}_i} \times 100\%$ and $\sum_{i=1}^{j} \mathrm{GI}_i \times \mathrm{CHO}_i$ respectively, where GI_i is the GI (as percentage) of the i^{th} food, and CHO_i is the amount of available carbohydrates in a serving of the i^{th} food.

Nutritional analysis

Nutrient intakes were estimated using the Australian Tables of Food Composition (NUTTAB90) [26] for the dietary data. Foods listed in the FFQ were categorised into major food categories and subcategories similar to those used for the 1995 Australian National Nutrition Survey [27]. Dairy sub-categorisation includes regular milk, reduced fat/skim milk, low fat cheese, regular cheese, reduced fat dairy dessert (e.g. low fat yoghurt), and medium fat dairy dessert (e.g. custard and regular yoghurt). For the purpose of this analysis, ***total dairy*** included all of the aforementioned dairy foods; ***low/reduced fat dairy*** included 'reduced fat/skim milk', 'reduced fat dairy dessert' and ‘low fat cheese’; while ***regular fat dairy*** included ‘regular milk’, ‘regular cheese’ and ‘medium fat dairy dessert’. Quartiles of dairy product consumption were based on serves of dairy consumed per day. The serving sizes used were 250 g for milk, 200 g for yoghurt, 250 mL for custards, and 40 g for cheeses. A detailed list of food categories and subcategories used in the analyses can be found in **Online Supplemental Table 1**.

Definitions of the health outcomes of interest

Incidence of MetSyn was defined as obesity (BMI ≥ 30) and at least two of the following [4]:

a) Elevated blood pressure: systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg, or on anti-hypertensive medications, and/or;
b) Triglycerides ≥ 1.7 mmol/L, and/or;
c) HDL cholesterol: females < 1.29 mmol/L or males < 1.03 mmol/L, and/or
d) Fasting blood glucose > 5.6 mmol/L or diagnosed T2DM.

A fasting blood sample was used to assess blood triglycerides, HDL cholesterol and blood glucose, and blood pressure was measured on the day of the eye examination using standard auscultatory methods. Incidence of type 2 diabetes was defined as self-reported physician diagnosis of type 2 diabetes plus taking medication for type 2 diabetes; or fasting blood glucose ≥ 7.0 mmol/L.

Statistical analyses

All statistical analyses were performed using SAS 9.1 (SAS Institute, Lane Cove, NSW, Australia). Of the 1 824 subjects who attended the examination at ten-years, 17 did not provide weight and/or height data and were excluded from analyses requiring BMI adjustment or stratification. Trend for subject characteristics across quartiles were tested by linear regression for continuous variables. Pearson χ^2 was used to test for difference between quartiles for categorical variables. Discrete time logistic regression modelling was used to investigate the associations between quartiles of total, regular fat and low/reduced fat dairy consumption and risk of MetSyn and type 2 diabetes, where change in dairy intake in the 10-y study period was taken intake account. There was no interaction between dairy intake and gender and smoking status and hence the results were not stratified based on these variables. The **base model** included adjustment for age and sex only. **Model 1** was further adjusted for smoking status, physical activity (METs), dietary glycemic load, fibre from vegetables (g), total energy intake and family history of type 2 diabetes. **Model 3** included all adjustments from Model 1, as well as systolic blood pressure (mmHg), BMI status (< 30 versus ≥ 30 kg/m^2; in non-stratified analyses only), HDL cholesterol (mmol/L), total cholesterol (mmol/L) and triglyceride (mmol/L). **Models 2** and **4** included all adjustments from **Models 1** and **3** respectively, plus additional adjustment for calcium (mg). Fibre from vegetables was used instead of total fibre as a previous study by our group had shown that this was the only type of fibre with a significant association to risk of type 2 diabetes mellitus [28].

Ethics approval

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the Sydney West Area Health Service and University of Sydney Human Research Ethics Committees. Written, informed consent was obtained from all subjects/patients.

RESULTS

The characteristics of the participants at baseline by quartiles of dairy intake are given in **Online Supplemental Table 2**. Participants who had higher total dairy intake had higher energy, calcium, total fat, saturated fat and vegetable fibre intake, dietary GL, as well as lower dietary GI (all $p_{\text{trend}} < 0.001$). Similar trends existed for quartiles of regular fat dairy consumption except for dietary GI, and there were more male ($p_{\text{trend}} < 0.001$) and smokers ($p_{\text{trend}} = 0.020$) in the higher quartiles. For low/reduced fat dairy, there were less male participants and smokers (both $p_{\text{trend}} < 0.001$) in the higher quartiles. Those who consumed more low/reduced fat dairy had higher energy ($p_{\text{trend}} = 0.003$), calcium ($p_{\text{trend}} < 0.001$) and vegetable fibre intakes ($p_{\text{trend}} = 0.005$), but lower intakes of total fat and saturated fat, as well as dietary GI (all $p_{\text{trend}} < 0.001$). There was no difference between the history of cardiovascular diseases of the subjects across the quartiles.

Table 1 shows the odds ratios of incident MetSyn according to quartiles of dairy intake. Subjects in the highest intake quartile of regular fat dairy at baseline had a significantly lower risk of MetSyn (**Model 1**: multivariate adjusted odds ratios (OR): 0.41; 95% confidence intervals (CI): 0.23 – 0.71; $p_{\text{trend}} = 0.004$). The association remains after further adjustment for calcium (**Model 2**: multivariate adjusted OR: 0.39; 95%CI: 0.22 – 0.70; $p_{\text{trend}} = 0.004$). No significant associations between baseline total dairy consumption and ten-year incidence of MetSyn were observed in any of the models tested. Subjects who had a higher intake of low/reduced fat dairy had an increased risk of MetSyn in the fully adjusted model (**Model 2;** $p_{\text{trend}} = 0.043$). There were no significant associations or trends between dairy consumption (total, low/reduced fat or regular fat) and risk of type 2 diabetes (**Online Supplemental Table 3**).

We further stratified the analyses by baseline BMI status (**Online Supplemental Table 4**), in the base model obese subjects in the highest quartile of regular fat dairy intake were found to be at a significantly reduced risk of type 2 diabetes (age and sex adjusted OR: 0.37; 95%CI: 0.16 – 0.88), and a significant trend was also observed ($p_{trend} = 0.030$). However, these associations did not persist after adjustment for confounders, or exclusion of the 14% of subjects who switch BMI category in the 10-year follow-up period (data not shown). No associations between total or low/reduced fat dairy intake and type 2 diabetes were observed among obese or non-obese subjects.

DISCUSSION

To our best knowledge this is the first Australian longitudinal study to examine the relationship between dairy food consumption and risk of incident MetSyn and type 2 diabetes. This study found that in a population-based cohort of older Australians, people who consumed approximately two serves of regular fat dairy compared to those who consumed less than one serve of regular fat dairy (median serve of lowest quartile = 0.1), had a ~59% reduced risk of developing MetSyn, a relationship not observed with total or low/reduced fat dairy consumption. There was also a significant association between regular fat dairy consumption and risk of type 2 diabetes amongst obese subjects but not in non-obese subjects.

We found that in the BMES population, an increased low/reduced fat dairy intake was associated with a lower daily saturated fat intake, which is protective against various components of MetSyn such as high triglycerides and hyperlipidemia. Our finding of an increase in risk of MetSyn among those who had higher intakes of low / reduced fat dairy (i.e. 3rd and 4th quartile) is therefore surprising. A recent study has found that daily consumption of low fat dairy products for 8 weeks did not improve metabolic markers related to MetSyn except for a slight decrease in systolic blood pressure [29], which may partly explain our results.

Due to its higher saturated fat content, regular fat / high fat dairy products were previously believed to increase the risk of type 2 diabetes as a high saturated fat intake is associated with insulin resistance [12, 30]. However, cohort studies and a meta-analysis now suggest otherwise, with higher regular fat / high fat dairy consumption being considered mostly neutral or protective for type 2 diabetes [18-20]. The results of the present study are consistent with these findings that higher regular fat dairy consumption may be protective of MetSyn and type 2 diabetes. The potential harmful effects of higher saturated fat from regular fat dairy products may have been offset by the protective components of regular fat dairy [31], such as *trans*-palmitoleate, a fatty acid nearly unique to ruminant foods [32, 33]. Circulating level of *trans*-palmitoleate was shown to be significantly associated with reduced risk of type 2 diabetes (Q5 vs Q1: 62% reduced risk, 95% CI: 38 – 76%, $p_{\text{trend}} < 0.001$) [32]. Moreover, the protective effect of *trans*-palmitoleate may be exerted via the suppression of hepatic fat synthesis, where the latter was strongly associated with insulin resistance [32, 34].

The association between dairy intake and ten-year incidence of type 2 diabetes could be mediated by weight status. Pereira *et al* [15] found that dairy consumption was associated with a reduced risk of abnormal glucose homeostasis only among subjects who were overweight at baseline. In agreement, we found a decreasing trend in risk of type 2 diabetes with increasing baseline intake of regular fat dairy only among obese subjects. However, these results must be interpreted with caution due to the small numbers of obese subjects in this subgroup. As suggested by Pereira *et al* [15], subjects who were of normal weight at baseline may have a healthier lifestyle or genetic factors which protect them from getting diabetes, and being overweight is associated with a greater propensity to develop type 2 diabetes. In addition, subjects at higher risk of type 2 diabetes may have been advised by healthcare professionals to switch from regular fat to low/reduced fat dairy and lose weight. It has previously been shown that higher low/reduced fat dairy intake, in conjunction with an energy restricted diet, may promote higher weight loss and reduce waist circumference [35], which may reduce the risk of type 2 diabetes. In the present study 14% of the subjects have switched BMI categories in the 10 year follow-up, however the results did not significantly change when these subjects were excluded from the analyses.

Further this protective effect observed in obese subjects did not persist after additional adjustment for confounding variables and calcium. Dairy products are primary sources of calcium in the Australian diet. While it is possible that dietary calcium may be responsible for the protective effect of dairy consumption [16, 36], the loss in significance could also be due to a loss of statistical power due to the large number of adjustments made as well as the relatively small number of cases in the weight sub-groups.

The strengths of this study include the use of a validated FFQ with a high correlation coefficient for calcium to assess the dairy consumption of the participants. This is likely to increase the plausibility of the associations found. The use of a well defined and generally accepted definition for MetSyn increased the reliability of the incidence data. The long follow up period also allowed us to better capture the incidence of MetSyn and type 2 diabetes which take many years to develop. The present study was, however, limited by the relatively small sample size and the low incidence of type 2 diabetes, therefore, we cannot rule out the possibility of chance findings. Furthermore, we are unable to rule out the possibility of residual confounding from other lifestyle risk factors for MetSyn and/or type 2 diabetes. In addition, the use of self-reported physician diagnosis may have resulted in some cases of undiagnosed type 2 diabetes, although this chance was minimized by the additional fasting blood glucose level criterion. While a 75-g oral glucose tolerance test is considered to be the gold standard of diabetes diagnosis in the clinical setting, due to the high costs and effort associated, it is not feasible and not commonly used in large scale epidemiological studies.

In conclusion, we found an inverse association between regular fat dairy consumption and risk of MetSyn among Australian older adults. Further studies are warranted to examine the association between weight status, dairy consumption and risk of type 2 diabetes.

Acknowledgement and conflict of interest: VMF and PM were involved in the collection of the original BMES data. VMF, BG, PM and TPG were involved in the conception of the present study. GB performed the statistical analyses under the direction of VMF. VMF, AMR, JCYL and TPG interpreted the data. JCYL drafted the manuscript. All authors were involved in the subsequent edits of the manuscript, and have read and approved the final manuscript.

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LITERATURE CITED

[1] Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Provisional report of a WHO Consultation. Diabet Med. 1998;15:539-53.

[2] Alberti KGMM, Zimmet P, Shaw J. The metabolic syndrome--a new worldwide definition. The Lancet. 2005;366:1059-62.

[3] Grundy SM, Brewer HB, Jr., Cleeman JI, Smith SC, Jr., Lenfant C, for the Conference P. Definition of Metabolic Syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association Conference on Scientific Issues Related to Definition. Circulation. 2004;109:433-8.

[4] International Diabetes Federation. The IDF consensus worldwide definition of the metabolic syndrome. Brussels: International Diabetes Federation; 2006.

[5] Elwood PC, Pickering JE, Fehily AM. Milk and dairy consumption, diabetes and the metabolic syndrome: the Caerphilly prospective study. J Epidemiol Community Health. 2007;61:695-8.

[6] Foreyt JP. Need for Lifestyle Intervention: How to Begin. Am J Cardiol. 2005;96:11-4.

[7] Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities study. Circulation. 2008;117:754-61.

[8] Australian Institute of Health and Welfare. Diabetes: Australian facts 2008. Diabetes series. Canberra: AIHW; 2008.

[9] Reinehr T, Kleber M, Toschke AM. Lifestyle intervention in obese children is associated with a decrease of the metabolic syndrome prevalence. Atherosclerosis. 2009;207:174-80.

[10] Cho YA, Kim J, Cho ER, Shin A. Dietary patterns and the prevalence of metabolic syndrome in Korean women. Nutr Metab Cardiovasc Dis. 2011;21:893-900.

[11] Horton ES. Effects of lifestyle changes to reduce risks of diabetes and associated cardiovascular risks: results from large scale efficacy trials. Obesity (Silver Spring). 2009;17 Suppl 3:S43-8.

[12] Salas-Salvado J, Martinez-Gonzalez MA, Bullo M, Ros E. The role of diet in the prevention of type 2 diabetes. Nutr Metab Cardiovasc Dis. 2011;21 Suppl 2:B32-48.

[13] Crichton GE, Bryan J, Buckley J, Murphy KJ. Dairy consumption and metabolic syndrome: a systematic review of findings and methodological issues. Obes Rev. 2011;12:e190-e201.

[14] Snijder MB, van Dam RM, Stehouwer CDA, Hiddink GJ, Heine RJ, Dekker JM. A prospective study of dairy consumption in relation to changes in metabolic risk factors: the Hoorn Study. Obesity (Silver Spring). 2008;16:706-9.

[15] Pereira MA, Jacobs DR, Jr., Van Horn L, Slattery ML, Kartashov AI, Ludwig DS. Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. Jama. 2002;287:2081-9.

[16] Fumeron F, Lamri A, Abi Khalil C, Jaziri R, Porchay-Baldérelli I, Lantieri O, et al. Dairy Consumption and the Incidence of Hyperglycemia and the Metabolic Syndrome. Diabetes Care. 2011;34:813-7.

[17] van Dam RM, Hu FB, Rosenberg L, Krishnan S, Palmer JR. Dietary calcium and magnesium, major food sources, and risk of type 2 diabetes in U.S. black women. Diabetes Care. 2006;29:2238-43.

[18] Tong X, Dong JY, Wu ZW, Li W, Qin LQ. Dairy consumption and risk of type 2 diabetes mellitus: a meta-analysis of cohort studies. Eur J Clin Nutr. 2011;65:1027-31.

[19] Liu S, Choi HK, Ford E, Song Y, Klevak A, Buring JE, et al. A prospective study of dairy intake and the risk of type 2 diabetes in women. Diabetes Care. 2006;29:1579-84.

[20] Choi HK, Willett WC, Stampfer MJ, Rimm E, Hu FB. Dairy consumption and risk of type 2 diabetes mellitus in men: a prospective study. Arch Intern Med. 2005;165:997-1003.

[21] Flood VM, Burlutsky G, Webb KL, Wang JJ, Smith WT, Mitchell P. Food and nutrient consumption trends in older Australians: a 10-year cohort study. Eur J Clin Nutr. 2010;64:603-13.

[22] Willett WC, Sampson L, Browne ML, Stampfer MJ, Rosner B, Hennekens CH, et al. The use of a self-administered questionnaire to assess diet four years in the past. Am J Epidemiol. 1988;127:188-99.

[23] Flood VM, Smith WT, Webb KL, Mitchell P. Issues in assessing the validity of nutrient data obtained from a food-frequency questionnaire: folate and vitamin B12 examples. Public Health Nutr. 2004;7:751-6.

[24] Smith W, Mitchell P, Reay EM, Webb K, Harvey PW. Validity and reproducibility of a self-administered food frequency questionnaire in older people. Aust N Z J Public Health. 1998;22:456-63.

[25] Foster-Powell K, Holt SH, Brand-Miller JC. International table of glycemic index and glycemic load values: 2002. Am J Clin Nutr. 2002;76:5-56.

[26] Department of Community Services and Health. NUTTAB90. Nutrient Data Table for Use in Australia. Canberra: Australian Government Publishing Service; 1990.

[27] McLennan W, Podger A. 1995 National Nutrition Survey: Nutrient Intakes and Physical Measurements. Canberra: Australian Bureau of Statistics; 1998.

[28] Barclay AW, Flood VM, Rochtchina E, Mitchell P, Brand-Miller JC. Glycemic index, dietary fiber, and risk of type 2 diabetes in a cohort of older Australians. Diabetes Care. 2007;30:2811-3.

[29] van Meijl LEC, Mensink RP. Low-fat dairy consumption reduces systolic blood pressure, but does not improve other metabolic risk parameters in overweight and obese subjects. Nutr Metab Cardiovasc Dis. 2011;21:355-61.

[30] Maron DJ, Fair JM, Haskell WL. Saturated fat intake and insulin resistance in men with coronary artery disease. The Stanford Coronary Risk Intervention Project Investigators and Staff. Circulation. 1991;84:2020-7.

[31] Aslibekyan S, Campos H, Baylin A. Biomarkers of dairy intake and the risk of heart disease. Nutr Metab Cardiovasc Dis. 2011.

[32] Mozaffarian D, Cao H, King IB, Lemaitre RN, Song X, Siscovick DS, et al. Trans-palmitoleic acid, metabolic risk factors, and new-onset diabetes in U.S. adults: a cohort study. Ann Intern Med. 2010;153:790-9.

[33] Micha R, King IB, Lemaitre RN, Rimm EB, Sacks F, Song X, et al. Food sources of individual plasma phospholipid trans fatty acid isomers: the Cardiovascular Health Study. Am J Clin Nutr. 2010;91:883-93.

[34] Lim JS, Mietus-Snyder M, Valente A, Schwarz JM, Lustig RH. The role of fructose in the pathogenesis of NAFLD and the metabolic syndrome. Nat Rev Gastroenterol Hepatol. 2010;7:251-64.

[35] Faghih S, Abadi AR, Hedayati M, Kimiagar SM. Comparison of the effects of cows' milk, fortified soy milk, and calcium supplement on weight and fat loss in premenopausal overweight and obese women. Nutr Metab Cardiovasc Dis. 2011;21:499-503.

[36] Drouillet P, Balkau B, Charles MA, Vol S, Bedouet M, Ducimetière P, et al. Calcium consumption and insulin resistance syndrome parameters. Data from the Epidemiological Study on the Insulin Resistance Syndrome (DESIR). Nutr Metab Cardiovasc Dis. 2007;17:486-92.

Table 1 - Odds ratios (95% Confidence Intervals) of incident metabolic syndrome according to quartiles of reduced/low fat, regular fat and total dairy product intake

	Q1 (ref)	Q2	Q3	Q4	*P* for trend
Total dairy					
n / cases	451 / 38	452 / 47	452 / 33	452 / 37	-
[a]Base model	1.00	1.26 (0.81 – 1.95)	0.82 (0.51 – 1.32)	0.96 (0.60 – 1.52)	0.516
[b]Model 1	1.00	1.21 (0.77 – 1.90)	0.72 (0.43 – 1.20)	0.86 (0.51 – 1.44)	0.332
[c]Model 2	1.00	1.12 (0.68 – 1.83)	0.62 (0.33 – 1.16)	0.62 (0.24 – 1.62)	0.242
Reduced/low fat dairy					
n / cases	465 / 22	438 / 38	459 / 54	445 / 41	-
[a]Base model	1.00	1.63 (0.95 – 2.81)	2.44 (1.46 – 4.07)	1.79 (1.05 – 3.07)	0.121
[b]Model 1	1.00	1.50 (0.86 – 2.60)	2.33 (1.39 – 3.91)	1.66 (0.95 – 2.89)	0.170
[c]Model 2	1.00	1.50 (0.86 – 2.61)	2.45 (1.45 – 4.13)	2.01 (1.05 – 3.83)	0.043
Regular fat dairy					
n / cases	436 / 45	467 / 41	456 / 44	448 / 25	-
[a]Base model	1.00	0.83 (0.54 – 1.29)	0.91 (0.59 – 1.40)	0.52 (0.62 – 0.86)	0.018
[b]Model 1	1.00	0.71 (0.45 – 1.13)	0.76 (0.48 – 1.20)	0.41 (0.23 – 0.71)	0.004
[c]Model 2	1.00	0.71 (0.45 – 1.12)	0.76 (0.48 – 1.20)	0.39 (0.22 – 0.70)	0.004

[a]Base model adjusted for age and sex
[b]Model 1: Base model with additional adjustments for smoking status, physical activity (metabolic equivalents), dietary glycemic load, fibre from vegetables (g), total energy intake and family history of type 2 diabetes
[c]Model 2: Model 1 with additional adjustment for calcium (mg)

Online Supplemental Table 2 – Subject characteristics at baseline by quartiles of dairy intake

	Q1	Q2	Q3	Q4	*p* value[a]
Total dairy					
Median intake (serves)	0.5	1.2	1.8	3.1	-
n	455	461	452	456	-
Age (y)	63.8 ± 8.5	63.5 ± 8.1	63.4 ± 8.3	63.9 ± 8.1	0.780
Male (%)	45.1	44.3	37.0	42.1	0.059
Smokers (%)	13.2	12.4	11.4	11.1	0.760
BMI (kg/m^2)	26.0 ± 4.5	26.3 ± 4.3	26.2 ± 4.1	26.2 ± 4.0	0.745
Energy (kJ)	7288.8 ± 2358.4	7923.7 ± 2134.2	8873.8 ± 2334.5	10167.4 ± 2567.5	<0.001
Calcium (mg)	483.0 ± 166.1	717.4 ± 136.3	962.7 ± 160.0	1461.0 ± 331.4	<0.001
Total fat (g)	63.3 ± 25.9	69.4 ± 23.7	79.3 ± 26.1	91.7 ± 32.7	<0.001
Saturated fat (g)	23.1 ± 11.1	26.4 ± 10.2	31.2 ± 11.6	38.0 ± 16.1	<0.001
Vegetable fibre (g)	9.2 ± 4.7	9.6 ± 4.0	10.7 ± 4.4	11.1 ± 5.2	<0.001
Glycemic index	58.6 ± 4.8	56.8 ± 4.0	55.7 ± 3.8	54.3 ± 3.9	<0.001
Glycemic load	118.8 ± 44.3	126.3 ± 39.1	137.9 ± 44.6	153.8 ± 45.7	<0.001
Medical history of					
CHD (%)	17.8	15.0	17.5	14.7	0.473
Hypertension (%)	55.4	49.3	49.7	50.7	0.228
AMI (%)	10.3	7.7	8.7	10.0	0.510
Angina (%)	14.3	11.7	14.4	11.2	0.337
Stroke (%)	5.4	5.1	5.3	6.7	0.723
Low / reduced fat					
Median intake (serves)	0.0	0.1	0.9	2.1	-
n	452	460	458	454	-
Age (y)	65.1 ± 8.8	62.1 ± 8.4	63.7 ± 8.0	63.8 ± 7.6	0.805
Male (%)	55.8	40.2	41.5	31.1	<0.001
Smokers (%)	16.6	15.2	9.2	7.2	<0.001
BMI (kg/m^2)	25.7 ± 4.1	26.3 ± 4.4	26.4 ± 4.2	26.2 ± 4.2	0.283
Energy (kJ)	8812.4 ± 2659.1	8147.5 ± 2685.0	8335.6 ± 2511.8	8959.6 ± 2414.2	0.003
Calcium (mg)	773.3 ± 366.4	717.6 ± 343.1	853.1 ± 286.8	1279.8 ± 422.7	<0.001
Total fat (g)	82.3 ± 30.1	75.6 ± 30.3	73.0 ± 29.5	72.8 ± 26.3	<0.001
Saturated fat (g)	34.1 ± 14.7	29.8 ± 14.0	27.4 ± 12.7	27.4 ± 12.0	<0.001
Vegetable fibre (g)	9.9 ± 5.1	9.9 ± 4.8	10.1 ± 4.4	10.6 ± 4.1	0.005
Glycemic index	58.3 ± 4.7	57.0 ± 4.5	56.1 ± 3.7	54.0 ± 3.6	<0.001
Glycemic load	138.1 ± 48.0	126.0 ± 46.1	130.7 ± 42.0	141.9 ± 43.9	0.089
Medical history of					
CHD (%)	17.0	16.7	16.0	15.3	0.901
Hypertension (%)	52.5	51.7	50.1	50.8	0.898
AMI (%)	9.7	9.2	8.6	9.3	0.947
Angina (%)	14.0	13.5	11.6	12.4	0.693
Stroke (%)	4.3	5.8	5.5	7.0	0.369
Regular fat					
Median intake (serves)	0.1	0.4	1.0	1.9	-
n	454	457	442	471	-
Age (y)	63.6 ± 7.8	64.0 ± 8.1	63.4 ± 8.4	63.6 ± 8.8	0.746

	Q1	Q2	Q3	Q4	*p* value[a]
Male (%)	35.7	39.8	44.3	48.4	<0.001
Smokers (%)	11.1	10.5	10.2	16.1	0.020
BMI (kg/m^2)	26.1 ± 4.3	26.1 ± 4.3	26.2 ± 4.3	26.2 ± 3.9	0.782
Energy (kJ)	7312.7 ± 2309.2	8141.2 ± 2241.0	8718.5 ± 2391.8	10026.6 ± 2603.5	<0.001
Calcium (mg)	705.8 ± 380.7	848.8 ± 404.4	856.8 ± 308.4	1198.9 ± 409.9	<0.001
Total fat (g)	58.2 ± 23.1	69.0 ± 24.3	78.3 ± 25.1	97.4 ± 29.0	<0.001
Saturated fat (g)	20.1 ± 9.4	25.6 ± 10.3	30.6 ± 10.5	41.9 ± 13.3	<0.001
Vegetable fibre (g)	9.3 ± 4.2	10.1 ± 4.2	10.2 ± 4.6	10.9 ± 5.3	<0.001
Glycemic index	56.6 ± 4.6	56.3 ± 4.4	56.5 ± 4.5	56.0 ± 4.2	0.084
Glycemic load	122.5 ± 44.3	129.2 ± 41.3	135.0 ± 43.9	149.4 ± 47.6	<0.001
Medical history of					
CHD (%)	16.3	15.2	18.4	15.1	0.494
Hypertension (%)	51.8	54.6	48.9	49.7	0.304
AMI (%)	8.6	9.7	9.2	9.2	0.951
Angina (%)	12.4	11.4	15.8	12.0	0.182
Stroke (%)	5.1	6.9	5.1	5.4	0.590

Values are expressed as mean ± SD except specified otherwise.

[a]*p* for trend tested by linear regression for continuous variables, and *p* value were tested by Pearson's χ^2 for categorical variables.

CHD – coronary heart diseases; AMI – acute myocardial infarction

Online Supplemental Table 3 - Odds ratios (95% Confidence Intervals) of incident type 2 diabetes according to quartiles of reduced/low fat, regular fat and total dairy product intake

	Q1 (ref)	Q2	Q3	Q4	*P* for trend
Total dairy					
n / cases	455 / 35	461 / 47	452 / 30	456 / 33	-
[a]Base model	1.00	1.33 (0.85 – 2.09)	0.80 (0.49 – 1.32)	0.90 (0.55 – 1.46)	0.310
[b]Model 3	1.00	1.15 (0.71 – 1.87)	0.80 (0.46 – 1.40)	0.96 (0.54 – 1.71)	0.710
[c]Model 4	1.00	1.29 (0.74 – 2.26)	1.00 (0.47 – 2.11)	1.50 (0.47 – 4.77)	0.568
Reduced/low fat dairy					
n / cases	452 / 32	460 / 44	458 / 33	454 / 36	-
[a]Base model	1.00	1.28 (0.79 – 2.05)	0.93 (0.56 – 1.53)	1.00 (0.61 – 1.64)	0.482
[b]Model 3	1.00	1.29 (0.77 – 2.14)	0.85 (0.49 – 1.46)	1.00 (0.58 – 1.71)	0.482
[c]Model 4	1.00	1.28 (0.77 – 2.14)	0.87 (0.50 – 1.52)	1.09 (0.57 – 2.09)	0.764
Regular fat dairy					
n / cases	454 / 41	457 / 37	442 / 39	471 / 28	-
[a]Base model	1.00	0.89 (0.56 – 1.41)	0.97 (0.62 – 1.53)	0.65 (0.40 – 1.07)	0.106
[b]Model 3	1.00	1.02 (0.62 – 1.69)	1.01 (0.61 – 1.67)	0.83 (0.47 – 1.48)	0.496
[c]Model 4	1.00	1.04 (0.63 – 1.72)	1.01 (0.61 – 1.68)	0.87 (0.48 – 1.57)	0.596

[a]Base model adjusted for age and sex
[b]Model 3: Model 1 with additional adjustments for systolic blood pressure (mmHg), baseline BMI status (< 30 vs ≥ 30 kg/m^2), HDL cholesterol (mmol/L), total cholesterol (mmol/L) and triglyceride (mmol/L).
[c]Model 4: Model 3 with additional adjustment for calcium (mg)

Online Supplemental Table 4 – Odds ratios (95% Confidence Intervals) of type 2 diabetes mellitus according to quartiles of reduced/low fat, regular fat and total dairy product intake, stratified by baseline BMI status

	BMI < 30					BMI ≥ 30				
Type of dairy	**Q1 (ref)**	**Q2**	**Q3**	**Q4**	***P* for trend**	**Q1 (ref)**	**Q2**	**Q3**	**Q4**	***P* for trend**
Total dairy										
n / case	378 / 21	376 / 26	374 / 22	384 / 24	-	74 / 13	79 / 20	73 / 8	69 / 9	-
[a]Base model	1.00	1.23 (0.68 – 2.21)	0.98 (0.54 – 1.81)	1.06 (0.59 – 1.93)	0.970	1.00	1.62 (0.77 – 3.41)	0.60 (0.24 – 1.50)	0.74 (0.30 – 1.81)	0.220
[b]Model 3	1.00	1.10 (0.58– 2.05)	1.18 (0.61 – 2.28)	1.17 (0.59 – 2.36)	0.664	1.00	1.02 (0.44 – 2.36)	0.29 (0.10 – 0.88)	0.45 (0.15 – 1.34)	0.078
[c]Model 4	1.00	1.04 (0.52 – 2.08)	1.07 (0.45 – 2.54)	0.96 (0.25 – 3.76)	0.952	1.00	2.16 (0.71 – 6.53)	1.03 (0.21– 4.97)	4.78 (0.44 – 52.47)	0.288
Reduced fat and/or low fat										
n / case	389 / 22	374 / 26	374 / 19	375 / 26	-	61 / 10	81 / 17	80 / 13	73 / 10	-
[a]Base model	1.00	1.15 (0.64 – 2.06)	0.80 (0.43 – 1.50)	1.06 (0.59 – 1.92)	0.903	1.00	1.24 (0.53 – 2.88)	0.99 (0.41 – 2.38)	0.84 (0.33 – 2.14)	0.438
[b]Model 3	1.00	1.14 (0.61 – 2.15)	0.73 (0.37 – 1.43)	1.02 (0.54 – 1.92)	0.763	1.00	1.50 (0.58 – 3.86)	1.09 (0.42 – 2.85)	0.73 (0.25 – 2.09)	0.230
[c]Model 4	1.00	1.15 (0.61 – 2.16)	0.70 (0.35 – 1.38)	0.86 (0.40 – 1.85)	0.413	1.00	1.67 (0.64 – 4.38)	1.72 (0.62 – 4.78)	1.73 (0.49 – 6.13)	0.622
Regular fat										
n / case	366 / 22	387 / 24	372 / 27	387 / 20	-	82 / 19	65 / 11	69 / 12	79 / 8	-
[a]Base model	1.00	1.05 (0.58 – 1.89)	1.25 (0.70 – 2.22)	0.89 (0.48 – 1.65)	0.708	1.00	0.68 (0.31 – 1.50)	0.66 (0.31 – 1.43)	0.37 (0.16 – 0.88)	0.030
[b]Model 3	1.00	1.23 (0.65 – 2.30)	1.40 (0.73 – 2.66)	1.30 (0.64 – 2.68)	0.509	1.00	0.88 (0.36 – 2.16)	0.65 (0.27 – 1.59)	0.42 (0.15 – 1.19)	0.079
[c]Model 4	1.00	1.21 (0.65 – 2.28)	1.40 (0.73 – 2.65)	1.25 (0.60 – 2.62)	0.580	1.00	1.02 (0.41 – 2.54)	0.64 (0.26 – 1.58)	0.57 (0.20 – 1.65)	0.201

BMI – Body mass index

[a]Base model adjusted for age and sex

[b]Model 3: Model 1 with additional adjustments for systolic blood pressure (mmHg), HDL cholesterol (mmol/L), total cholesterol (mmol/L) and triglyceride (mmol/L).

[c]Model 4: Model 3 with additional adjustment for calcium (mg)